Development of a Learning-Support System for Science Using Collaboration and Body Movement for Hearing-Impaired Children: Learning Support for Plant Germination and Growth Conditions

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Abstract. In this study, we aimed to develop a full-body gaming-style collaboration and learning support system for a proxy topic of plant germination and growth conditions while focusing on improving the learning experiences of hearing-impaired children. The system is based upon a quiz game activity in which participants learn about plant germination and growth conditions via collaboration and question-answering with their friends. Through the use of a collaborative gaming environment, hearing-impaired learners can repeatedly simulate experiments and observations on germination and growth to accelerate and enhance learning. The system is built with standard information and communications technologies and is evaluate the system to assess its effectiveness. The evaluation experiment revealed the system supported collaborative game play with enjoyment, empathy for others, and interaction for hearing-impaired children. We conclude that the system is useful in supporting hearing-impaired children in learning science through collaboration. Furthermore, we believe that system, which uses body movement and collaboration, might be applicable to other learning areas.

Keywords: Science education · Hearing-impaired children · Collaboration

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1 Introduction

In this study, we develop a full-body gaming-style collaboration and learning support system for a proxy scientific topic of plant germination and growth conditions while focusing on improving the learning experiences of hearing-impaired children. For this purpose, we leverage standard information and communication technologies (ICT) to provide a learning environment within which children play and learn with their fellow students using sensing and animation capabilities. We evaluate the system in terms of the total effect of the collaborative and full-body gaming experience on learning for hearing-impaired children.

Science education for children is vital to promoting a culture of scientific thinking, problem-solving competency, and innovation. It further encourages accession to scientific careers and other professions underpinned with knowledge and innovation [1]. Based on the rights of persons with disabilities [2], this issue becomes even more critical for hearing-impaired children, who face significant obstacles to learning via collaboration, owing to their difficulty in obtaining audio information [3, 4]. Thus we pursue a partial solution to overcoming this learning deficit by tackling the proxy topic of scientific naivety related to plant germination and growth conditions.

Education researchers have often addressed the challenge of eradicating naïve concepts held by young science students [5, 6]. Naïve concepts regarding plant germination and growth are common misconceptions [7]. In Japan, learners are quite likely to carry their naïve conceptions into their scholastic experiments. For example, many young people assume that sunlight and soil are the basic requirements needed by seeds to germinate. Thus, they often confuse the distinction between plant germination and growth conditions [8]. The challenge, therefore, is providing an enjoyable system that helps children learn about the three plant germination conditions and the five successful growth conditions during elementary school [9]. The three germination conditions are water, oxygen, and appropriate temperatures. The five growth conditions are water, sunlight, oxygen, appropriate temperatures, and fertilizer. Children can learn about these things through a variety of experiments and observations. However, doing so requires considerable time and effort. This poses an even greater problem for hearing-impaired children.

To address these problems, we aim to develop a support system based on gaming activity using body movement and animation. Through the use of a gaming environment, hearing-impaired learners can repeatedly simulate experiments and observations on germination and growth to accelerate and enhance learning. Moreover, in a collaborative learning environment, participants work on tasks together to promote interaction and knowledge building and build a shared conceptualization of problem solving [10]. We believe that, by using body movements, hearing-impaired children can be further enabled to communicate and interact with others. Body movement is a helpful method of expressing ideas and it helps participants understand one another using visual imagery. Past studies have reported that hearing-impaired children who participated in interactive experiences involving collaboration and body movement (e.g., a puppet show) demonstrated heightened feelings of enjoyment, presence, participation, absorption, and immersion [11, 12]. Research has also shown that collaboration and physical activity enhance immersion in these situations.

2 Game System

2.1 Framework

Figure 1 illustrates the framework of the system used to create the gaming experience. The setup comprises two screens, two projectors, a Kinect sensor, and one control computer. The system is based upon a quiz game activity in which participants learn about plant germination and growth conditions via collaboration and question-answering. One set of a screen and projector is applied to a wall, and the other is applied to the floor. The wall screen in Fig. 1 displays the seeds or seedlings of the plant referred to in the quiz and the area for participant responses. The floor screen shows the quiz answer options. Figure 2 shows the display contents image of the wall screen. Figure 3 illustrates the display contents of the floor screen (i.e., nine answer options displayed in a 3 × 3 configuration. When standing upon the answer options, participants' movements and locations are captured by a Kinect sensor. Players' answers are then displayed on the wall screen and synchronized.

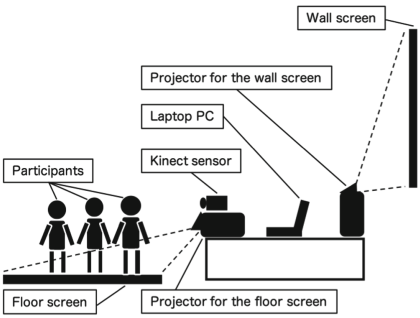

Fig. 1. System overview

2.2 Quiz Game Overview

Table 1 provides an overview of the germination and growth conditions quiz based on carrots, tomatoes, potatoes, and pepper seeds. The germination quiz offers nine answer options at a time. For the growth conditions portion of the quiz, participants are presented with "oxygen" and "appropriate temperature" as two given conditions, and they are asked to choose the remaining three from a set of nine valid or invalid options (i.e., "water," "sunlight," "wind," "caterpillars," "birds," "fertilizers," "earthworms," "electricity," and "music"). The correct answers include "water," "sunlight," and "fertilizer."

At the start of the game, participants are divided into groups of three. As one group plays the game, the two other observe and collaborate on how they will play when it

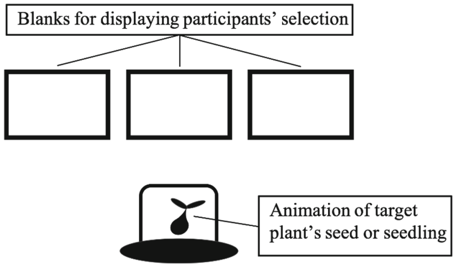

Fig. 2. Display content image on the wall screen

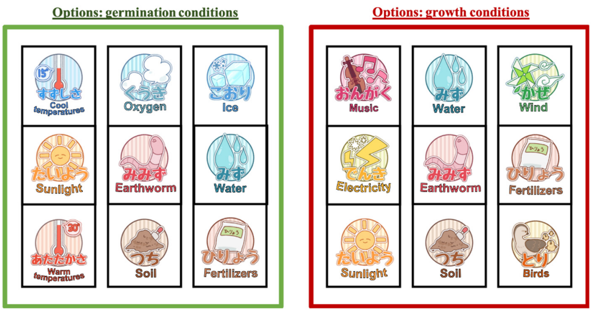

Fig. 3. Display content on the floor screen

Table 1. Germination and growth conditions.

Plants	Correct options		
Germination conditions			
Carrot seed	Water	Air (oxygen)	Cool temperatures
Tomato seed	Water	Air (oxygen)	Warm temperatures
Potato seed	Water	Air (oxygen)	Cool temperatures
Pepper seed	Water	Air (oxygen)	Warm temperatures
Growth conditions			
Carrot seedling	Water	Sunlight	Fertilizers
Tomato seedling	Water	Sunlight	Fertilizers
Potato seedling	Water	Sunlight	Fertilizers
Pepper seedling	Water	Sunlight	Fertilizers

becomes their turn. The group playing the game is shown nine options in the 3 × 3 grid projected on the floor. There is only one correct answer per column, and each player selects one answer from their three options by standing on it. The participants can change their positions during collaboration, selecting different floor-screen options and deciding upon their final answers to the quiz.

Finally, when a player decides upon an answer, he/she presses the appropriate selection point on the floor screen, signaling the system to judge whether their answer is correct. If all three players are correct, the system then projects an animation of the seed (or seedling) growing on the wall screen. If an answer is incorrect, the system displays “incorrect” and the players try again.

3 Evaluation Experiment

3.1 Methods

Participants: Participants included 17 hearing-impaired children in their 1st-to-3rd years of elementary school (6–9 years of age).

Tasks and Procedures: The participants were divided into six groups of three. A supporter joined the group lacking a participant. Each group played the game at least twice. Figure 4 shows one group playing the quiz game. They all had chosen invalid answers and been promoted to try once again by game characters. Following the activity, each student completed a paper questionnaire. 10 items were developed based on the Game Experience Questionnaire’s [13, 14] social presence module, which is used to examine game players’ psychological and behavioral participation in social gaming experiences from three perspectives: psychological involvement-empathy, psychological involvement-negative feelings, and behavioral involvement. In this evaluation, each of the three perspectives was further divided into specific options to make answering easier for the participants and to examine the effectiveness of collaborative playing. Discussions were held with teachers from the special support schools attended by the participants to help understand the question options.

Fig. 4. Game playing

Psychological involvement-empathy featured five options related to enjoyment with, understanding of, and gaining information from other participants: 1) “I empathized with the other;" 2) "I paid close attention to others during the quiz game;" 3) "I found it enjoyable during the quiz game to be with others;" 4) "When the others seemed to be having fun, I also enjoyed myself;" and 5) "I admired the others."

Psychological involvement-negative feelings featured one option: 6) "I was influenced by the mood of others during the quiz game."

Behavioral involvement included five options related to interaction and cooperation to solve the quiz: 7) "My actions depended on the actions of others while playing the quiz game;" 8) "The actions of others depended on my actions while playing the quiz gam;" 9) "I felt connected to others while playing the quiz game;" and 10) "the others paid close attention to me."

For each item, the participants replied using a seven-stage Likert scale with the following options: "strongly agree," "agree," "somewhat agree," "no strong opinion," "somewhat disagree," "disagree," and "strongly disagree."

Study date: The study was conducted on November 1, 2018.

3.2 Results

Participant replies were classified into positive responses of "strongly agree," "agree," and "somewhat agree." Neutral or negative responses of "no strong opinion," "somewhat disagree," "disagree," and "strongly disagree" were also classified. Reverse scoring was necessary so that lower scores indicated higher positive affectivity. The results show that the number of positive answers was higher than that of neutral or negative answers for all items. We analyzed the differences in count between positive, neutral, and negative replies for each item using a 1×2 Fisher's exact test.

Table 2 shows participant responses to the questions. In all items, the number of positive answers was higher than that of neutral or negative answers. From the perspective of psychological involvement-empathy, there was a significant difference in two population proportions in all five items. As expected, responses favored more positive answers than neutral or negative replies. This indicates that, in the collaborative quiz game play of the developed system, the participants experienced empathy toward others in the game experience of discussion and answering.

From the perspective of psychological involvement-negative feelings, there was a significant difference in the two population proportions for an item. Positive answers were favored over neutral or negative replies. This suggests that, in the game, the participants were strongly influenced by the moods of others.

From the point of view of behavioral involvement, there was a significant difference in two population proportions for all items with the exception of item 7. It revealed more positive answers than neutral or negative replies. This indicates that, in the collaborative quiz game play of the developed system, the participants experienced interaction with others via multiple players. However, participants felt that others did not depend on their action while playing the quiz game.

Table 2. Germination and growth conditions.

	Items	Strongly agree	Agree	No strong opinion	Disagree	Strongly disagree
	Psychological Involvement-Empathy					
1	I empathized with the other**	11	2	2	0	1
2	I paid close attention to others during the quiz game**	12	3	1	0	0
3	I found it enjoyable during the quiz game to be with others**	14	2	0	0	0
4	When the others seemed to be having fun, I also enjoyed myself**	13	2	1	0	0
5	I admired the others**	13	1	1	1	0
	Psychological Involvement – Negative Feelings					
6	I was influenced the mood of others during the quiz game**	11	2	2	1	0
	Behavioral Involvement					
7	My actions depended on the actions of others while playing the quiz game$^{n.s}$	9	1	3	0	3
8	The actions of others depended on my actions while playing the quiz game*	10	1	2	0	3
9	I felt connected to others while playing the quiz game**	9	3	2	1	1
10	The other(s) paid close attention to me**	12	3	1	0	0

N = 16, $p^{**} < 0.01$, $p^{*} < 0.05$, n.s.: non-significance

4 Conclusions

In this study, we developed a learning science-support system specifically for hearing-impaired children. We designed the system to support collaboration and body movement using ICTs while focusing on plant germination and growth conditions.

The evaluation experiment revealed that the system supported collaborative game play with enjoyment, empathy for others, and interaction. However, while playing the quiz game, the participants were strongly influenced by others' moods. Results suggest that the atmosphere of the group supported the notion that scientific thinking could strongly influence the decisions of participants. Conversely, participants did not appear to be convinced that their actions affected those of others.

Based upon these study results, we can conclude that the system we developed can be used as a successful way to support hearing-impaired children's learning science with collaboration. Furthermore, we believe that our system, which uses body movement and collaboration, might be applicable to other learning areas.

Moving forward, we need to evaluate the effectiveness of the system's success in learning support in greater detail. In addition, we need to improve the system and/or quiz game format to encourage children to make decisions based upon scientific ideas.

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